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SWASH PLATE TYPE VARIABLE CAPACITY COMPRESSOR FOR SUPERCRITICAL REFRIGERATING CYCLE

TECHNICAL FIELD

The present invention relates to a swash plate type variable capacity compressor which is used for a supercritical refrigerating cycle.

BACKGROUND ART

Conventionally, various structures are known for a suction valve and a discharge valve of a swash plate type variable capacity compressor which compresses a refrigerant of a refrigerating cycle. For example, it is known that the discharge valve has a valve body press-contacted in an elastically deformed state to the valve seat of a discharge port. The structure of this type of discharge valve is disclosed in, for example, Japanese Utility Model Laid-Open Publication No. Sho 61-44074 and Japanese Patent Application Laid-Open Publication No. 2001-153000.

Besides, the refrigerant of the refrigerating cycle is mixed with a lubricating oil, and it is necessary to consider the surface tension of the lubricating oil which enters the gap between the valve body and the valve seat in order to secure good opening and closing operations of the suction valve and the discharge valve. The surface tension of the lubricating oil is important to secure the hermeticity of the valve but becomes a resistance when the valve body opens. Therefore, if the surface tension is larger than it is required, the valve body operates with delay, and vibrations and noises of the compressor increase. Japanese Patent

Laid-Open Publications No. Hei 7-167058 and No. Hei 7-180662 disclose a valve structure which is configured to leave a small gap between the valve body and the valve seat even when the valve body is in a closed state in order to deal with the problems. The suction valve and the discharge valve of the swash plate type variable capacity compressor used for the refrigerating cycle were considered important to have a structure which should prevent vibrations, noises and the like.

As the refrigerant for the refrigerating cycle, a fleon refrigerant including a substitute fleon has been used extensively. But developments are being made to replace it with CO_2 considering the global environment in these years. A refrigerating cycle using CO_2 as the refrigerant has a very high inner pressure in comparison with the refrigerating cycle using a fleon refrigerant, and particularly a pressure on a high-pressure side happens to exceed the critical point of the refrigerant depending on use conditions such as a temperature. The critical point is a limit on the high-pressure side (namely, a limit on a high-temperature side) in a state that a gas layer and a liquid layer coexist and is an end point at one end of a vapor pressure curve. A pressure, a temperature and a density at the critical point become a critical pressure, a critical temperature and a critical density, respectively. Especially, when the pressure exceeds the critical point of the refrigerant in a radiator of the refrigerating cycle, the refrigerant does not condensate. This type of supercritical refrigerating cycle is mounted on, for example, an automobile and used for air conditioning of the car interior.

A compressor to be used for the supercritical refrigerating

cycle is also described in, for example, Japanese Patent Laid-Open Publication No. 2002-257037. The compressor described in this publication is configured such that the piston stroke is variable depending on the inclination of a swash plate which is disposed rotatably. The piston is held to be reciprocally movable in the cylinder, and the cylinder is provided with a suction valve for sucking a refrigerant and a discharge valve for discharging the refrigerant. The refrigerant which circulates the refrigerating cycle is sucked into the cylinder through the suction valve, compressed and discharged out of the cylinder through the discharge valve. For the refrigerating cycle used for air conditioning of a car interior, the compressor is coupled with a motor vehicle engine and operated by the engine power.

The supercritical refrigerating cycle has a pressure resistance performance which is quite different from the conventional refrigerating cycle using the fleon refrigerant, and the compressor for the supercritical refrigerating cycle has been also demanded to have a more outstanding structure considering its pressure resistance performance and the like.

For example, according to the above-described Japanese Patent Laid-Open Publication No. 2002-257037, the compressor for the supercritical refrigerating cycle has a high operating pressure. Therefore, even a leakage of the refrigerant through a small gap degrades the performance. And, the compressor described in this publication is provided with an elastic member which pushes the valve body of the suction valve against the valve seat to eliminate a gap which is produced between the valve body and the valve seat.

However, when an elastic member for pushing the valve body against the valve seat is provided, the number of parts increases, which result in causing disadvantages of complicating the structure and requiring a precision thereof, an increase in cost and the like. According to the endurance test conducted by the inventors of the present invention, it was found that the elastic member involves unavoidable problem of causing degradation in endurance.

Besides, for the supercritical refrigerating cycle, the compressor, which is operated by the power of a motor vehicle engine, is important to secure a startup property when the driving engine is started. In other words, when this compressor is compared with a compressor of the refrigerating cycle using a fleon refrigerant, the cylinder capacity becomes relatively small because of a problem of pressure resistance. Therefore, an influence of the leakage of the refrigerant at the suction valve or the discharge valve is conspicuous and the seat surfaces of the valve body and the valve seat also become small. And, there are problems that the lubricating oil which enters between them becomes rather insufficient, and good opening and closing operations of the valve body are hardly secured. And, a seat failure due to such a shortage of the oil becomes a cause of delaying the generation of suction and discharge actions of the refrigerant from particularly a pressure-balanced state (with a very small flow rate of the refrigerant). Thus, it is presumed that with the existing compressor, the number of rotations on startup, namely the number of rotations of the swash plate when the refrigerant is started to be compressed, is larger than it is required.

As a compressor to be mounted on a car, there is known a

clutchless compressor which is coupled with a motor vehicle engine without via a clutch. For the clutchless compressor, its swash plate is rotating constantly even when the refrigerant is not compressed, and the piston's minimum stroke is generally about 5% or less of the maximum stroke. In recent years, such a clutchless compressor has been also regarded as having a significant problem that the number of rotations on startup is decreased.

Especially, with the supercritical refrigerating cycle, the refrigerant has a pressure of about 7.2 MPa in an atmosphere of 30°C when the compressor is actuated. On the contrary, with the refrigerating cycle using a fleon refrigerant, the refrigerant has a pressure of about 0.67 MPa in an atmosphere of 30°C when the compressor is actusted. Therefore, the compressor of the supercritical refrigerating cycle secures a high pressure resistance by setting the cylinder capacity and the port opening area small. Generally, the compressor of the supercritical refrigerating cycle has a cylinder with a bore diameter of 15.0 to 21.0 mm, a capacity of 20 to 33 cm^3, and a suction valve and a discharge valve with a port's opening area of 7.0 to 29.0 mm^2. On the contrary, the compressor of the refrigerating cycle using the fleon refrigerant has a cylinder with a bore diameter of 32 to 40 mm, a capacity of 90 cm^3 to 170 cm^3, and a suction valve and a discharge valve with a port's opening area of 38.5 to 113.0 mm^2.

Further, when the compressor of the supercritical refrigerating cycle and the compressor of the refrigerating cycle using the fleon refrigerant have the same machining accuracy for the cylinder and the piston, the supercritical refrigerating cycle

has a relatively large gap between the cylinder and the piston with respect to the cylinder capacity when the piston reaches the top dead center. This is also one of the causes to increase the number of rotations at the time of actuation of the supercritical refrigerating cycle.

The present invention has been made in view of the above circumstances and an object is to achieve an improvement of performance of a swash plate type variable capacity compressor for a supercritical refrigerating cycle.

DISCLOSURE OF THE INVENTION

The invention described in claim 1 of the present application is a swash plate type variable capacity compressor to be used for a supercritical refrigerating cycle comprising: a swash plate which is disposed rotatably, a piston which is coupled with the swash plate and a cylinder which holds the piston movably, the cylinder is provided with a suction valve for sucking a refrigerant of the supercritical refrigerating cycle and a discharge valve for discharging the refrigerant, wherein the suction valve has valve bodies having flexibility attached to suction ports for sucking the refrigerant, and the swash plate type variable capacity compressor has the valve bodies press-contacted in an elastically deformed state against the valve seats of the suction ports to decrease the number of rotations of the swash plate when the refrigerant is started to be compressed. With this structure, the performance of the swash plate type variable capacity compressor for a supercritical refrigerating cycle is improved securely.

The inventors of the present invention have prototyped various types of valve structures and conducted experiments in order to obtain a suitable valve structure for the swash plate type variable capacity displacement compressor for a supercritical refrigerating cycle. According to the conducted experiments, it was found that the elimination of the gaps between the valve bodies and the valve seats described above was more significant for the suction valve than for the discharge valve in view of the reduction of the number of rotations on startup. Further, the suction valve, which was most effective to secure a startup property, endurance and good opening and closing operations of the valve bodies, has the valve bodies having flexibility fitted to the suction ports for sucking the refrigerant and the valve bodies press-contacted in a slightly elastically deformed state against the valve seats of the suction ports. The valve bodies of the suction valve are designed considering an appropriate inner stress applied after fitting to the suction ports.

With this structure, even if the seat surfaces of the valve bodies and the valve seats are rather narrow, such a seat defect can be avoided efficiently. As a result, the number of rotations of the swash plate when the refrigerant is started to be compressed can be decreased securely.

The cases that the valve bodies of the suction valve were press-contacted and not in an elastically deformed state against the valve seats were compared by experiments. The number of rotations on startup in the case of press-contacted was 30 to 70% of that on startup in the case of not press-contacted. In other words, the reduction of the number of rotations of the swash plate

when the refrigerant is started to be compressed according to the present invention is based on the comparison with the case that the valve bodies of the suction valve are not press-contacted in an elastically deformed state against the valve seats.

As described above, the present invention has been made with attention paid to a quite significant structure in detail of the swash plate type variable capacity compressor used for a supercritical refrigerating cycle. As a result, the swash plate type variable capacity compressor has achieved a conspicuous effect of considerably improving the performance of the compressor by devising a very simple structure.

The invention described in claim 2 of the present application is the swash plate type variable capacity compressor according to claim 1, wherein the valve body has deflection of 1 mm or less when the valve bodies are fitted to the suction ports, and the valve bodies receive an external force of 1.8 N or less from the valve seats of the suction ports. In other words, the seating property of the valve bodies and the valve seats can be secured finely, while securing the smooth opening and closing operations of the valve bodies, by determining the deflection of the valve bodies to 1 mm or less and the external force received by the valve bodies from the valve seats of the suction ports to 1.8 N or less.

The invention described in claim 3 of the present application is the swash plate type variable capacity compressor according to claim 1 or 2, wherein the supercritical refrigerating cycle is a refrigerating cycle for air conditioning of a car interior to be mounted in an automobile, and the swash plate type variable capacity compressor is a clutchless compressor which is coupled

with a motor vehicle engine without via a clutch. In other words, the swash plate type variable capacity compressor of the present invention has securely reduced the number of rotations of the swash plate when the refrigerant is started to be compressed and can be used quite suitably as a clutchless compressor used for a refrigerating cycle for air conditioning of a car interior.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram schematically showing a supercritical refrigerating cycle according to an embodiment of the present invention;

Fig. 2 is a sectional view showing a swash plate type variable capacity compressor for a supercritical refrigerating cycle according to an embodiment of the present invention;

Fig. 3 is a front view showing a valve plate and a cylinder-side valve body plate according to an embodiment of the present invention;

Fig. 4 is a front view showing a valve plate and a rear housing-side valve body plate according to an embodiment of the present invention;

Fig. 5 is a sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention;

Fig. 6 is an exploded sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention;

Fig. 7 is a sectional view showing a suction valve and a discharge valve according to an embodiment of the present

invention;

Fig. 8 is a sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention;

Fig. 9 is a comparative graph of the number of rotations on startup before and after an improvement according to an embodiment of the present invention;

Fig. 10 is a sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention;

Fig. 11 is an exploded sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention;

Fig. 12 is a sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention; and

Fig. 13 is an exploded sectional view showing a suction valve and a discharge valve according to an embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the present invention will be described below. As shown in Fig. 1, a supercritical refrigerating cycle 1 of this embodiment is a refrigerating cycle for air conditioning of a car interior mounted on a car and provided with a swash plate type variable capacity compressor 10 which compresses a refrigerant, a radiator 20 which cools the refrigerant compressed by the compressor 10, an expansion valve 30 which reduces the pressure

to expand the refrigerant cooled by the radiator 20, an evaporator 40 which evaporates the refrigerant decompressed by the expansion valve 30, an accumulator 50 which separates the refrigerant flowed out of the evaporator 40 into a gas layer and a liquid layer and sends the refrigerant of the gas layer to the compressor 10, and an inner heat exchanger 60 which performs heat exchange between a high-pressure side refrigerant and a low-pressure side refrigerant to improve the efficiency of the cycle. As the refrigerant, CO_2 is used, a high-pressure side pressure of the supercritical refrigerating cycle 1 exceeds the critical point of the refrigerant depending on use conditions such as a temperature and the like. Further, the refrigerant contains the lubricating oil which smoothly drives the compressor 10.

As shown in Fig. 2, the swash plate type variable capacity compressor 10 of this embodiment is provided with a front housing 110, a cylinder block 120, a rear housing 130, a valve plate 140, a drive shaft 200 which is provided rotalably, a lag plate 300 which is provided on the drive shaft 200, a swash plate 400 which is mounted on the drive shaft 200 and the lag plate 300, a piston 500 which is coupled to the swash plate 400 via a shoe 410, a cylinder 600 which holds the piston 500 to be movable reciprocally, and a control valve 700 which controls a pressure acting on the piston 500.

This swash plate type variable displacement compressor 10 controls a discharge amount of the refrigerant by taking the refrigerant into the cylinder 600, compressing and discharging it by moving the piston 500 reciprocally by rotating the swash plate 400 together with the drive shaft 200 and the lag plate 300,

and changing an inclination of the swash plate 400 and a stroke of the piston 500 by controlling a pressure of the control valve 700 acting on the piston 500. The piston 500 is set to have a minimum stroke which is about 5% or less of a maximum stroke. The piston 500 and the cylinder 600 are in plural and at equal intervals about the axis of rotation of the drive shaft 200.

The drive shaft 200 is installed in the front housing 110 and the cylinder block 120 via bearings. Further, the drive shaft 200 is coupled to an engine, which is a motor vehicle engine, without via a clutch. In other words, the swash plate type variable capacity compressor 10 is a so-called clutchless compressor. The interior of the front housing 110 is a crank chamber 111 in which the lag plate 300 and the swash plate 400 are disposed. The cylinder block 120 is a member which constitutes a plurality of cylinders 600.

The lag plate 300 is a member which is fixed to the drive shaft 200 and has an arm portion 310, which couples the swash plate 400, disposed on its required portion. The swash plate 400 is provided with a guide portion 420 to which a shoe 410 is fitted, and mounted on the drive shaft 200 to be slidable and to have a variable inclined angle. A spring 430 is disposed between the lag plate 300 and the swash plate 400 to push the swash plate 400 and the piston 500 toward the cylinder 600 to some extent.

The individual pistons 500 are tethered to the shoe 410 and in contact with a bore 610 of the cylinder 600 and are moved reciprocally with respect to the cylinder 600 when the swash plate 400 rotates.

The control valve 700 controls the inner pressure of the

crank chamber 111. The inclination of the swash plate 400 and the stroke of the piston 500 are variable depending on the inner pressure of the crank chamber 111.

The valve plate 140 is a member which constitutes a suction valve 150 for sucking the refrigerant into the cylinder 600 and a discharge valve 160 for discharging the refrigerant from the cylinder 600, and which is disposed between the cylinder block 120 and the rear housing 130. A cylinder-side valve body plate 151 and a rear housing-side valve body plate 161 to be described in detail later are screwed to either surface of the valve plate 140. The individual cylinder blocks 120 are provided with the suction valve 150 and the discharge valve 160 by disposing the valve plate 140. The refrigerant is compressed between the piston 500 and the valve plate 140.

The rear housing 130 mounts the control valve 700 and also constitutes a suction chamber 131 and a discharge chamber 132 with respect to the valve plate 140.

Then, a flow path for flowing the refrigerant is disposed at required portions of the compressor 10, and a low-pressure gas before compression circulated through the refrigerating cycle 1 is guided into the suction chamber 131. The low-pressure gas in the suction chamber 131 is sucked into the cylinder 600 through the suction valve 150 when the piston 500 moves to return, and it becomes a high-pressure gas and is led into the discharge chamber 132 through the discharge valve 160 when the piston 500 moves forward. The high-pressure gas in the discharge chamber 132 circulates the refrigerating cycle again.

The control valve 700 is communicated with the crank chamber

111, the suction chamber 131 and the discharge chamber 132 through predetermined passages, and it is so configured that when the pressure of the low-pressure gas drops, a bellows provided in its interior swells to open the valve, and the high-pressure gas is guided to the crank chamber 111. Further,when the pressure of the low-pressure gas increases, the bellows contracts to close the valve, and the high-pressure gas guided to the crank chamber 111 is cut off.

The swash plate 400 moves reciprocally in a state that the average of the inside pressures of the individual cylinders 600 and the inside pressure of the crank chamber 111 are balanced. In other words, the inclination of the swash plate 400 and the stroke of the piston 500 are controlled by an opening degree of the control valve 700, and the discharge amount of the high-pressure gas increases when the stroke of the piston 500 increases and decreases when it becomes small.

The pressure of the refrigerant at the time when the swash plate type variable capacity compressor 10 is actuated is about 7.2 MPa in an atmosphere at 30°C. Further, the bore 610 of the cylinder 600 has a diameter of 15.0 - 21.0 mm, the cylinder 600 has a volume of 20 - 33 cm^3, individual ports 141, 142 at the suction valve 150 and the discharge valve 160 have an opening area of 7.0 - 29.0 mm^2.

Next, the valve structure of this embodiment will be described with reference to Fig. 3 through Fig. 8. The valve plate 140 is a member which is provided with the plural suction ports 141 which communicate the individual cylinders 600 with the suction chamber 131, and the plural discharge ports 142 which communicate

the individual cylinders 600 with the discharge chamber 132. Further, the cylinder-side valve body plate 151 is a member which is provided with plural valve bodies 152 of the suction valve 150 corresponding to the individual suction ports 141, and plural holes 153 corresponding to the individual discharge ports 142. Besides, the rear housing-side valve body plate 161 is a member which is provided with plural valve bodies 162 of the discharge valve 160 corresponding to the individual discharge ports 142, and plural holes 163 corresponding to the suction ports 141 (see Fig. 3 and Fig. 4).

The suction valve 150 of this embodiment has the valve bodies 152 having flexibility fitted to the suction ports 141 which suck the refrigerant into the cylinders 600. The valve bodies 152 of the suction valve 150 are press-contacted in a slightly elastically deformed state against one surface of the valve plate 140 as valve seats of the suction ports 141. Similarly, the discharge valve 160 of this embodiment has the valve bodies 162 having flexibility fitted to the discharge ports 142 which discharge the refrigerant from the insides of the cylinders 600. The valve bodies 162 of the discharge valve 160 are press-contacted in a slightly elastically deformed state against the other surface of the valve plate 140 as valve seats of the discharge ports 142. In the drawing, 164 is a retainer which regulates the opening degree of the valve body 162 of the discharge valve 160. The retainer 164 is screwed to the valve plate 140 (see Fig. 5).

Specifically, the valve bodies 152 of the suction valve 150 formed on the cylinder-side valve body plate 151 are plastically deformed in a curved form to protrude the leading ends toward the

valve plate 140 (see Fig. 6) to mount the cylinder-side valve body plate 151 on the valve plate 140 and are elastically deformed by force. The valve bodies 152 are plastically deformed by pressing, and deflection $\ddot{a}_1$ when attached to the suction ports 141 is 1 mm or less (more specifically, 50 to 200 ìm). A thickness of a material for the valve bodies 152 of the suction valve 150 is desirably 0.2 - 0.3 mm, and it is 0.25 mm in this embodiment. This material has a modulus of longitudinal elasticity of about 2.06×10^5 N/mm^2. And, an external force P which is received by the valve bodies 152 of the suction valve 150 from the valve seats of the ports 141 is 1.8 N or less to secure smooth opening and closing operations of the valve bodies 152. A more desirable range of the external force P is 1.2 N or less, and the most desirable range is 0.2 - 0.7 N. For example, if the valve body 152 has a spring constant k of about 5.0 N/mm and a deflection $\ddot{a}_1$ of 240 ìm, its external force P becomes about 1.2 N from $k=P/\ddot{a}_1$. Otherwise, when the spring constant k of the valve body 152 is about 4.0 N/mm and deflection $\ddot{a}_1$ is 150 ìm, its external force P becomes about 0.6 N. The spring constant k depends on the modulus of longitudinal elasticity of the material and the shape of the valve body 152.

The basic structure of the valve bodies 162 of the discharge valve 160 disposed on the rear housing-side valve body plate 161 is the same as that of the valve bodies 152 of the above-described suction valve 150. In other words, deflection $\ddot{a}_2$ of the valve bodies 162 of the discharge valve 160 is 1 mm or less, and the external force P which is received by the valve bodies 162 of the discharge valve 160 from the valve seats of the ports 142 is 1.8 N or less.

The surfaces of the individual valve bodies 152, 162 are coated with PTFE or the like in order to improve a seating property with the valve seats. The valve bodies 152 of the suction valve 150 and the valve bodies 162 of the discharge valve 160 each perform opening and closing operations depending on a differential pressure between the crank chamber 111, the suction chamber 131 and the discharge chamber 132 (see Fig. 7 and Fig. 8).

The inventors of the present invention have repeated comparative experiments about the number of rotations on startup under different conditions on the swash plate type variable capacity compressor 10 of this embodiment and one with its cylinder-side valve body plate 151 changed. The changed cylinder-side valve body plate has a flat shape, and the valve bodies 152 of the suction valve 150 are not press-contacted in an elastically deformed state against the surface of the valve plate 140 as valve seats of the suction ports 141. As a result, the number of rotations of the swash plate type variable capacity compressor 10 of this embodiment at the time of actuation was in a range of 30 to 70% of that at the time of actuation of one with the cylinder-side valve body plate 151 changed. For example, when a swash plate type variable capacity compressor, which has the valve bodies of the suction valve not press-contacted in an elastically deformed state against the valve seats and has the number of rotations of about 700 rpm at the time of actuation, is structured with the valve bodies changed and press-contacted to the valve seats in a slightly elastically deformed state, the number of rotations at the time of actuation was decreased to about 300 rpm. Fig. 9 is a comparative graph of the number of rotations

on startup before and after the exchange of the valve bodies of the suction valve, namely before and after the improvement. According to the experiment, the swash plate type variable capacity compressor 10 of this embodiment was proved that the number of rotations of the swash plate when the refrigerant was started to be compressed was decreased securely.

The shape of the valve bodies 152 of the suction valve 150 and the shape of the valve bodies 162 of the discharge valve 160 can be changed their designs appropriately and are not limited to those exemplified in the drawings. For example, as shown in Fig. 10 and Fig. 11, the valve bodies 152 of the suction valve 150 or the valve bodies 162 of the discharge valve 160 can also be structured to form their leading ends into a hemispherical shape such that the spherical surfaces are contacted to the edges of the circular suction ports 141 or discharge ports 142. The leading end may be formed by pressing. The valve bodies 152 of the suction valve 150 or the valve bodies 162 of the discharge valve 160 have a male screw part B, which is screw-engaged, with a female thread portion N which is formed in the valve plate 140, to thereby elastically deform their leading ends in a state pressed against the edges of the suction ports 141 or the discharge ports 142.

Or, it may also be structured as shown in Fig. 12 and Fig. 13 such that the flat valve bodies 152, 162 are elastically deformed to press-contact against the surface of the curved valve plate 140. In this case, the plastic deformation of the valve bodies 152,162 can be omitted.

INDUSTRIAL APPLICABILITY

The swash plate type variable capacity compressor of the present invention can be used suitably as a compressor of a supercritical refrigerating cycle having a high-pressure side pressure exceeding the critical point of a refrigerant.